Thermal histories and parent body(ies) of EH chondrites: Evidences from new highly equilibrated EHs (Y793225, 82189, 8404, 8414 and 86004), Y. LIN [1, 2] and M. KIMURA[1], [1]Department of Earth Sciences, Ibaraki university, Mito 310, Japan; [2]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China.

Introduction

Enstatite chondrites, the most reduced among chondrites, are classified into EH and EL groups[1]. Different from EL group predominant with EL6 type, EH group has abundant EH3 members but only a few EH5 meteorites collected. Recently, LEW88180 was reported as a new EH5[2] or the first EH6[3]. In this work, we report petrography and mineral chemistry of 5 new Antarctic enstatite chondrites, *i.e.* Y793225 (E6), Y82189 (E6), Y8404 (E5), Y8414 (E4) and Y86004 (E6)[4]. Y8404, 8414 and 86004 are probably paired and could be classified together with Y82189 as EH6. Y793225 shows intermediate mineral chemistry between EH and EL, it is an anomalous EH6 or may represent a new group of enstatite chondrites. We noticed that EH chondrites could be divided into two subgroups, one has higher MnS-content of niningerite and shows evidences for a slower cooling history in comparison with the other.

Petrography

In our polished thin sections, no any chondrule was recognized. All of the 5 meteorites are well recrystallized, with grain size > 20-40 µm. Orthoenstatite is predominant. Plagioclase and silica are also common. Phlogopite is found in Y82189, being ~10-30 µm in size and usually coexisting with plagioclase and silica. This is the first reported occurrence of phlogopite in enstatite meteorites. Major opaque phases of all 5 meteorites are metallic FeNi and troilite. Niningerite is the third most abundant, except in Y793225 which contains more abundant daubreelite instead of the (Mg, Mn, Fe)S phase. Niningerite in Y82189 contains abundant troilite lamellae, while those in Y8404, 8414 and 86004 rarely enclose troilite. Schreibersite is common but not found in Y8414. Occurrences of the other opaque phases are significantly different among these meteorites. Besides Y793225, daubreelite is found only in Y82189, but coexisting with unidentified Cr-sulfides (phase A/B)[5] different from the grains in Y793225 free of phase A/B. Sphalerite is fairly common in Y82189, rare in Y8404, 8414 and 86004, and not found in Y793225. Perryite occurs as an accessory phase coexisting with kamacite only in Y793225 and Y82135. Several grains of djerfisherite are found only in Y82189. Oldhamite (weathered) can be recognized in Y8414 and 8404. It is obvious that mineral occurrences among Y8404, 8414 and 86004 are quite similar, but clearly distinguished from Y793225 and Y82189.

Mineral chemistry

Enstatites in all 5 meteorites are nearly pure with minor CaO (Y793225: 0.38-0.61 %, and the others: 0.06-0.32 %), FeO (Y793225: <0.09 %, the others: <0.77 %) and Al_2O_3 (<0.23 %). An-content of plagioclase is 10-13 mol% in Y793225, but <0.4 mol% in the others. The Or-contents are indistinguishable among them (4-6 mol%). Phlogopite contains 4.1-5.9 % F, 0.07-0.36 % FeO with atomic K/(K+Na) ratio of 0.85-0.91. Metallic FeNi in Y8404, 8414 and 86004 are Ni-rich and P-bearing (6.87-8.0 %Ni and 0.12-0.25 % P), different from the Ni-poor and P-free grains in Y793225 (2.92-7.20 %Ni) and Y82189 (4.73-6.85 %Ni). The Si-contents are 2.52-2.91 % in Y8404, 8414 and 86004, 1.42-3.48 % in Y793225, and 2.78-3.78 % in Y82189. Similarly, compositions of schreibersites in Y8404 and Y86004 are the same (5.99-6.44 %Ni, 0.25-0.36 %Co), also distinguished from the grains in Y793225 (13.1-17.3 %Ni, 0.07-0.16 %Co) and Y82189 (17.3-20.3 %Ni, 0.05-0.18 %Co). Niningerites in Y8404, 8414 and 86004 have similar compositions with higher FeS-content (46.1-58.1 mol%) but lower MnS-content (5.2-7.3 mol%) than the grains in Y82189 (19.4-23.4 mol% FeS, 9.5-11.2 mol% MnS) (Fig. 1). The (Mg, Mn, Fe)S phase in Y793225 has a composition of 36.3-42.9 mol% MgS, 41.3-49.4 mol% MnS and 13.7-16.3 mol% FeS, just the intermediate between niningerite and alabandite (Fig. 1). Troilite contains higher Cr in Y8404, 8414 and 86004 (1.69-2.06 %) than in Y82189 (0.88-1.79 %) and Y793225 (0.52-1.67 %), while the Ti-content is significantly higher in Y793225 (0.8-1.91 %) than the others (0.14-0.53 %). Compositions of daubreelites are different between Y82189 (0.17-0.66 %Mn, upto 0.78 %Zn) and Y793225 (0.86-2.56 %Mn, <0.13% Zn). FeS-content of sphalerite is much higher in Y86004 (58.8±0.8 mol%) than Y82189 (46.3±2.0 mol%).

Discussion

Classification: Y8404 and Y8414 were classified as E5 and E4[4], respectively. However, no any chondrule was recognized in our sections. Both of them are well recrystallized similar to the other three E6 meteorites. Furthermore, the similar petrography and identical mineral chemistry among Y8404, 8414 and 86004 suggest that they are likely paired. From the occurrence of niningerite, high Si-contents of metallic FeNi, low Ni-contents of schreibersite, and low An-contents of plagioclase, Y82189, 8404, 8414 and 86004 should be classified as EH6. Chemical compositions of metallic phases of Y793225 are in the range of EH group. However, the An-content of plagioclase, MnS-content of the (Mg, Mn, Fe)S phase, Mn-content of daubreelite, and Ti-content of troilite are between those of EH and EL, or close to EL chondrites. There is no other meteorite reported before to have intermediate mineral chemistry between EH and EL groups. Alabandite in LEW87119 has an atomic MnS/MgS ratio close to 1, but contains very high FeS-content (32.9 wt%) and plotted on an extrapolated line of EL group[2]. We proposed that Y793225 may be classified as anomalous EH6 or represent a new group of enstatite chondrites.

Thermal histories of the 5 enstatite chondrites: Although all 5 meteorites are classified as type 6, they experienced different thermal histories. Based on the phase diagram of niningerite-troilite[6], the average closure temperature of niningerites in Y8404, 8414 and 86004 are calculated to be 790_C, much higher than those in Y82189 and Y793225 («600_C). The significantly lower Ni-contents of schreibersite in Y8404, 8414 and 86004 also indicate the higher closure temperatures in comparison with schreibersites in Y82189 and Y793225 based on Fe-Ni-P diagrams[7]. Using the FeS-T-P diagram of sphalerite[8], closure temperature of sphalerite in Y86004 is >400_C higher than that in Y82189, given their parent body(ies) smaller than 230km in radius[9]. The higher closure temperatures of niningerite, schreibersite and sphalerite in Y8404, 8414 and 86004 than those in Y82189 and 793225 suggest a faster cooling history of the former in comparison with the latter.

Parent bodies of enstatite chondrites: Except for a few newly reported Antarctic EL6 chondrites (LEW 87119, 88714, 88135)[2], EL6 chondrites show slow cooling[3]. In contrast, EH chondrites were reported to have various thermal histories[2, 3, 10]. This is also confirmed by the different closure temperatures among the 5 new Antarctic enstatite chondrites. We notice that there is a relationship between the thermal history and MnS-content of niningerite for EH4-6s. Meteorites (*e.g.* Y82189, St. Marks, South Oman, Kaidun III and Y74370) favoring for a slow cooling history have high MnS-contents of niningerite similar to that of Qingzhen (EH3), while the others (*e.g.* Y8404, 8414, 86004, Saint Sauveur, Abee, and LEW88180) show evidences for a fast cooling history and have low MnS-contents of niningerite which are close to that of Y69001 (EH3) (Fig. 1). The low FeS-content of niningerite in Y69001 is likely primordial, hence it dose not indicate a low closure temperature as the other EH4-6s. Only Adhi Kot is out of the rule, which favors for a fast cooling history but has high MnS-content of niningerite, and Indarch shows the intermediate properties (Fig. 1). The above correlationship cannot easily be explained by different buried depths or locations in the parent body, neither by impact histories. It seems that there are two parent bodies of EH chondrites: one contains MnS-rich niningerite and has a slow cooling history in comparison with the other.

Conclusions

(1) Four of the 5 enstatite chondrites studied here are classified as EH6, and Y86004, Y8404 and 8414 are probably paired; (2) Y793225 may be an anomalous EH6 or represent a new group between EH and EL chondrites; (3) Mineral chemistries of Y82189 and Y793225 suggest slow cooling rates, while that of Y8604, Y8414 and Y8404 favors for a fast cooling history; (4) Most EH chondrites can be classified into two subgroups, one shows evidences for a faster cooling history and has lower MnS-content of niningerite in comparison with the other; (5) Occurrence of phlogopite in Y83189 is the first report in enstatite meteorites.

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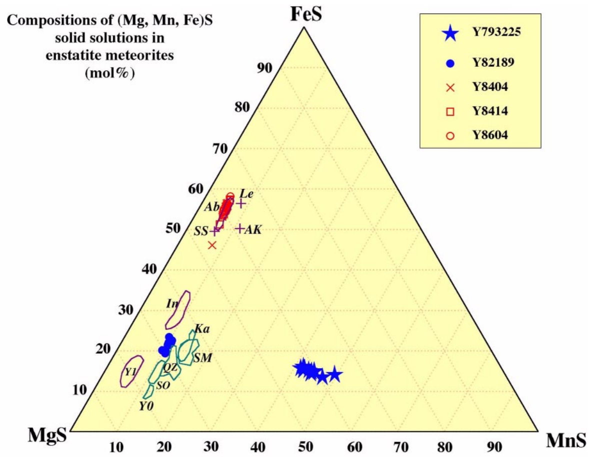

Figure 1. Compositions of (Mg, Mn, Fe)S phases in EH chondrites. For EH4-6 chondrites, the MnS-contents of FeS-rich niningerites are similar to that of Y69001 (EH3) and lower than those of FeS-poor niningerites which overlap with Qingzhen (EH3). Adhi Kot is an exception of the rule, and Indarch shows intermediate contents of FeS and MnS. The composition of (Mg, Mn, Fe)S phase in Y793225 is plotted between niningerite and alabandite. Abbreviation: St. Marks (SM), South Oman (SO), Kaidun III (Ka), Y74370 (Y0), and Qingzhen (QZ); Saint Sauveur (SS), Abee (Ab), LEW88180 (Le), and Y69001 (Y1). Literature: data of the ranges after [10], and the averages after [2, 11].